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Design and Implementation Low Cost of Photovoltaic Monitoring System Network Based on LoRaWAN

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Abstract. The photovoltaic systems sector is in full renovation continually demanding a new system that allows the user to monitor his project from long distance. One of the systems that is currently being implemented in photovoltaic farms is known as the Internet of Things. Through this system, it is intended that the user can know in the real time the status of his photovoltaic systems panels. This paper presents a new solution based on LoRaWAN technology that allows the user to have the necessary information to achieve high efficient of the photovoltaic systems panels. This system is to design and implement a new measuring circuit for measuring the output voltage and current of the PV panels from long distance by using LoRa Technology. To test the correct functioning of the device, two tests have been carried out. The first one corresponds to an essay in which the maximum distance at which a node can communicate with the gateway is measured. While the second test means measuring the voltage and current output of the photovoltaic panel of the full system. The main advantages of the final circuit can be used to monitor PV panels with low-cost, and to have high-efficiency performance from long distance.

Keywords: —LoRaWAN, LoRa, IOT, smart monitoring, photovoltaic system, voltage sensor ,current sensor.

1. Introduction

Currently, the electricity generated by photovoltaic installations is economically very competitive due to the great technological advance and the reduction of investment costs, experienced in recent years. In the last years, a considerable number of on grid systems and isolated photovoltaic systems have been installed in hard-to-reach rural areas. The main problem is associated with photovoltaic installations with the absence of a remote monitoring system that allows adequate monitoring of its operation.

The lack of a monitoring system can cause the interruption of the electricity supply to users in isolated areas. The isolated photovoltaic systems installed require the use of wireless measuring devices and computer platforms, which allow the real-time monitoring of their operation [1-8]. The monitoring systems allow to speed up the operation and maintenance of the components that make up the photovoltaic generation system. Today, the wide variety of commercial systems for monitoring photovoltaic installations have several disadvantages such as:



- Dependence on the manufacturer's software and high maintenance cost.
- Considerable energy consumption and limited autonomous control.
- Limited storage capacity.

These disadvantages encourage the development of monitoring systems based on free software and hardware. In this paper, the implementation of the low cost of photovoltaic monitoring system network based on LoRaWAN, treatment and visualization of information of photovoltaic systems, is carried out using open source software and hardware, thus offering a modular system, easily adaptable and with a great capacity for integrate into new technological trends.

After acquisition of data from the sensors, voltage and current have direct communication with the Arduino + LoRa shield system. This is determined as "NODE"; The node sends the data through LoRa communication to the respective Gateway (Hub). The Gateway sends the data of each node (three nodes) to a public cloud for saving and smart applications for monitoring.

At present, the existence of computer services and applications, as well as wireless remote monitoring systems allow the transmission and storage of a large volume of recorded data. The cloud computing platforms represent the best solution for handling large volumes of information and Web services. In addition, they allow guaranteeing adequate characteristics of reliability, scalability and accessibility [9-15].

2. Smart Monitoring System

In this part, the IoT solution for the monitoring application sites will be discussed. Implementing one of the new technologies in the IoT sector "LoRa", which has low energy consumption and long distance (greater than 10 Km in line of sight) between the transmitting device and the receiving device.

2.1. Internet of Things (IOT)

The IoT is an applied area of electronic embedded systems, whose main objective is the use of the internet as a means of communicating these systems with each other. This is for the exchange of information on their operating status without the need for intervention by a human user. So the IoT is an applied area that seeks to develop electronic circuits that allow the internet connection to devices, with the aim that they can exchange data with other internet users. Currently, large multinationals such as Cisco and Microsoft develop and offer multiple applications such as the following:

- Priority of saving lives is by using intelligent transport solutions accelerating traffic flows, reducing fuel consumption.
- Improving system reliability can be done by using smart power grid.
- Predict problems are by using control sensors in diagnostic instrument.
- Provide Data-based systems in the infrastructure of "smart cities" and "smart grid".

2.2. LoRaWAN Technology

The long-range and low-power (LoRa) wireless platform is the predominant technological option for the construction of IoT networks worldwide. This technology uses frequency spectra for public use in the ISM band (such as Wi-Fi and Bluetooth). It uses a spread spectrum modulation in the band less than GHz which allows long range with distances greater than 10 kilometres, with high node capacity (greater than 100 nodes).

The smart IoT applications have improved the ways they interact by addressing some of the biggest defy of climate change pollution in cities and communities, early warning of natural disasters and saving lives. Companies also have benefit through improvements in operations and efficiency. That is why in this technology the result is a very efficient long-range communication system allowing communications with battery-powered equipment. Figure1 shows the full architecture of the LoRaWAN technology [16].

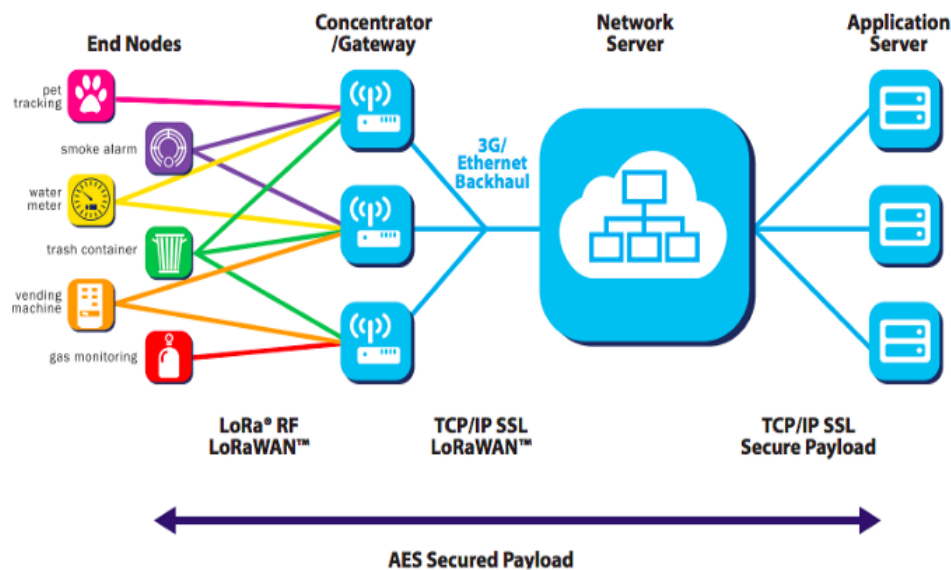


Figure 1. The architecture of the LoRa technology [16]

3. System Overview

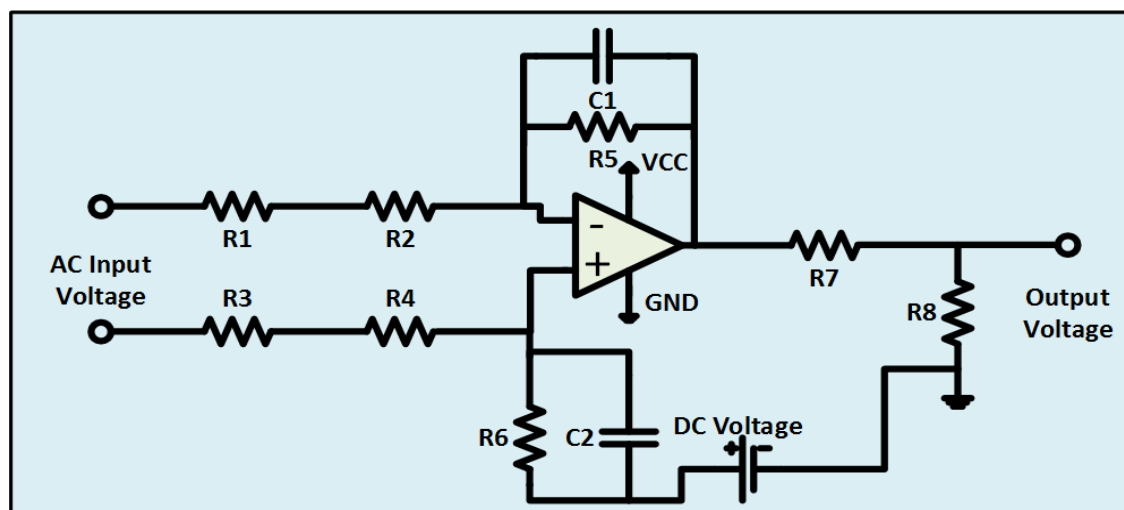
In order to implement the designed system, the latest generation instrument and sensors used which in turn has a low cost, without neglecting aspects such as reliability and efficiency.

3.1. Voltage and Current Measurement Circuit

In this part, end node measurement circuit will be discussed. This circuit is designed to show the components of voltage and current circuits.

3.1.1 Voltage measurement circuit: First of all, we design alternating AC voltage measurement sensor to measure the AC voltage. In this paper, the researcher uses operational amplifier (OA) for a step down voltage. The OA is used a different amplifier of the input voltage to compare between the positive and negative voltage. Normally, we step down the AC or DC voltage to less than 5/3.3 volt. Because, the ADC Arduino or microcontroller cannot measure the negative voltage directly. The circuit diagram of the different amplifier of the voltage sensor is present in the Figure 2(a), and the full practical circuit is shown in the Figure 2(b).

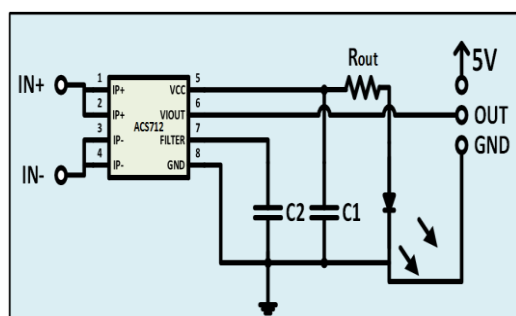
3.1.2 Current measurement circuit: Allegro® ACS712 offers economical and accurate solutions for AC or DC current for the power system in industrial systems. These sensors are good for measuring and measuring total energy consumption of full systems in power electronic. The Allegro® ACS712 current sensor is up to 30A DC or AC current. ACS712 Low Current Sensor provides an analog effort signal that changes linearly with the sensor current. To calibrate the results, firstly, one has to adjust the output offset at the desired level (with no current (zero current) on the sensor lines, read the output values). The main specifications of these sensors are low cost, current limit is 30A and the sensitivity is 66 mV/A. The current sensors circuit of the ACS712 is presented in the Figure3(a) and a model of this sensor is presented in the Figure 3(b) [17].



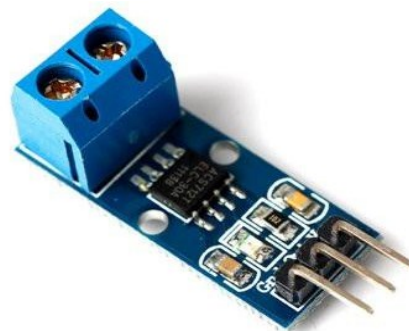
(a)



(b)

Figure 2. Voltage sensor: a) circuit diagram and b) final circuit design.

(a)



(b)

Figure 3. ACS712 Current sensor: a) circuit diagram and b) sensor model [17].

3.1.3 Arduino UNO R3.0: The Arduino UNO is an open-source electronic prototype platform based on flexible and easy-to-use hardware and software. It is designed for master, designers, as a hobby and for any researcher interested in creating environments or interactive objects. Arduino can feel the circumference by receiving inputs from a variety of sensors (Analog and digital) and can affect its surroundings by controlling any instruments connected with it like motors and lights and other electrical and electronic instruments.

Arduino programming software is an open source platform, available for extension by users and experienced programmers. The programming language can be expanded and developed through C++ libraries and the people who want to understand the instructions and technical details can make the jump from Arduino to the programming in AVR C language on which it is based.

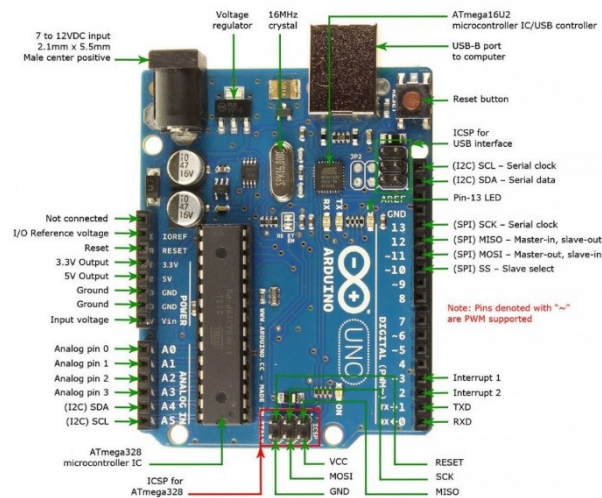


Figure 4. The Arduino UNO R3.0 kit

The Arduino UNO R3.0 in the Figure 4 is designed based on ATMEGA8 and ATMEGA168 microcontrollers from Atmel. Module plans are published under Creative Commons license. So, experienced circuit designers can create their own version of the module [18].

3.2. LoRaWAN Communication Network

For the implementation of the designed system, the latest generation tools are used and, in turn, are low cost, without neglecting aspects such as knowledge and experience with them.

3.2.1 Lora dragino shield: The LoRa Shield is designed to meet the different needs reflected in the wide range of applications. This Shield in the Figure 5(a) is a long-range transceiver that works for the Arduino system and is based on the open source library. The LoRa Shield allows the users to send and receive data from long ranges at low data rates. Provides wide-spread extended spectrum communication and high interference immunity. Based on the SEMTECH SX1276 / SX1278 chip in the Figure 5(b), the network was designed in this paper; it is aimed at professional wireless sensor network applications, such as irrigation systems, smart measurement, smart cities, build automation, and smartphone detection, .. etc. The properties of the SEMTECH SX1276 / SX1278 chip are presented below [19]:

- Compatible with Arduino Board voltage (3.3v or 5v)
- Frequency bandwidth: 915 MHZ / 868 MHZ / 433 MHZ (Factory default)
- Low power consumption and compatible with Arduino UNO, Mega, Leonardo, DUE.

3.2.2 Lora Dragino LG-01-S Gateway: The LG01-S is a simple open source LoRa Gateway channel. It allows the user to connect the LoRa wireless network to the internet and cloud with an IP network via Wi-Fi, Ethernet, GSM cellular. The LoRa wireless connection allows users to send and receive data and access extremely long ranges distance with low data rates. It provides a wide range of ultra-long spectrum communication and high interference immunity. LG01-S has a Wi-Fi interface, an Ethernet port and a USB host port. These interfaces ports provide users with flexible methods to connect their project and sensors networks to the Internet.

LG01-S runs the open source network system. The user can freely modify the source programming file or compile of the system to support their custom applications. The LG01-S Lora Dragino gateway is shown in the Figure 2. LG01-S runs the open source network system. The user can freely modify the source file or compile the system to support their custom applications. The LG01-S Lora Dragino gateway is shown in the Figure 6 [19].



Figure 5. The LoRa Dragino shield technology for Arduino[19].

The main specifications of this gateway are below:

- open source system and easy to program
- Low power consumption
- Internet connection via LAN, Wi-Fi, GSM
- LoRa bandwidth available at 433/868/915/920 MHz



Figure 6. The LG01-S LoRa Dragino gateway[19].

4. Full System Description

The smart photovoltaic monitoring system is developed in a three solar cell sites in Middle Technical University-Iraq. The proposed system can measure AC voltage up to 400 V and the current of up to 30A, The system can be developed to be able to read voltages up to 800 V. In the photovoltaic system, considered voltage and current are the most important elements to know a user or consumer perspective. Figure7 shows the full description of the photovoltaic developed system to monitor voltage and current based on LoRaWAN.

4.1. Software design of the full system

The flowchart diagram of the software design of the smart control nodes is shown in Figure 8(a). The main program of the photovoltaic system measures the output voltage and current from panels cells, after measuring, setting initialization of the wireless mode set LoRa module to send the results to the gateway.

When receiving terminal of LoRa, the gateway received the data (voltage and current) from transmitting terminal of the full system (three nodes). It will send the data in two ways, the first way is sending data to cloud for saving by using Ethernet cable and the second way to user interface program for monitoring by using Wi-Fi network. Figure 8(b) presents the flowchart of the LoRa gateway of the full monitoring system.

4.2. System test and results

Two programs were designed to monitor the whole photovoltaic system. The first one is for desktop application that was written by using Microsoft C++. The second program was designed to monitor the data by using android smartphone application.

The monitoring software application of the LoRaWAN system in the Figure 9 is a new Android smartphones application. This application was designed to work on an Android instrument only. The monitoring application software is designed by using MIT App Inventor 2 (open-source platform from google for Android application) [20]. Figure 9 shows the windows of the smartphone application program of LoRaWAN network. Figure 9(a) is the main screen of the monitoring application before Wi-Fi connection without any results from photovoltaic nodes (sites), and Figure 9(b) presents the window after connected with results (voltage and current for three sites).

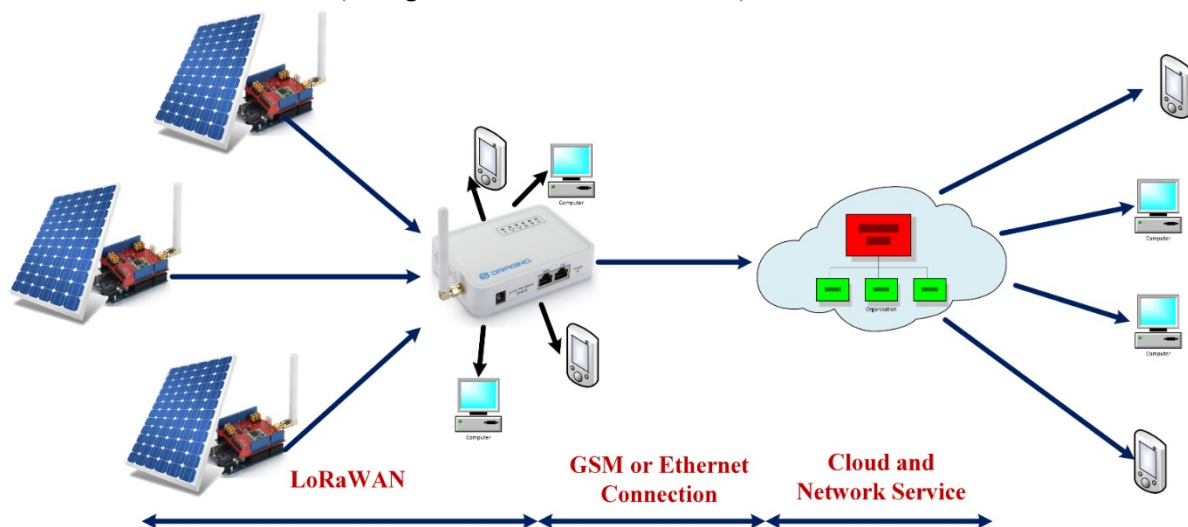


Figure 7. The architecture of LoRaWAN for monitoring the photovoltaic system.

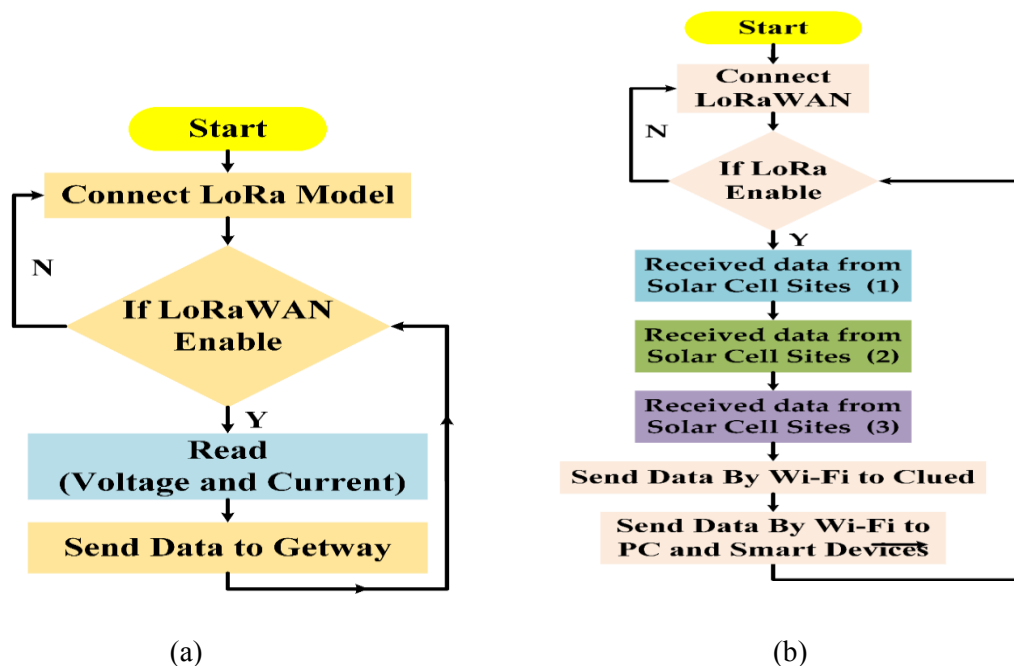


Figure 8. a) The flowchart detailing of measuring and control node and b) The flowchart detailing of gateway.

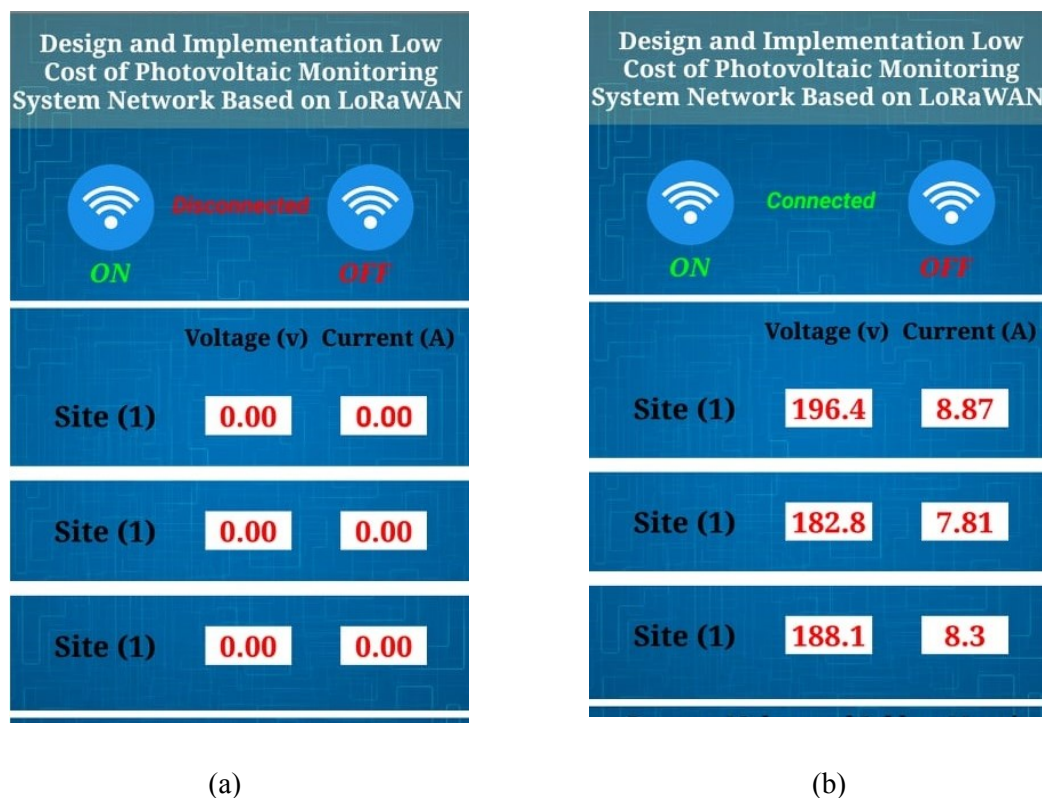


Figure 9. User interface application: a) Wi-Fi not connected without results and b) Wi-Fi connected and with results.

5. Conclusions

This paper proposes a photovoltaic panels monitoring system for Middle Technical University- Iraq by using LoRaWAN technology. The proposed system meets the objective of allowing the solar panel to be monitored from any point or device with internet access. This system is composed of a main board responsible for capturing data and sending information via LoRa. A gateway responsible for requesting data at a defined time interval and sending the information received to a server responsible for storing data. Finally, an Android application is responsible for displaying the statuses, such as voltage and current in real time.

LoRaWAN works as a great alternative to GSM as it is cheaper and does not require a data plan, just an internet connection to the gateway to upload the data to cloud computing. One of the main difficulties that are found in the proposed system in this paper is in relation to the communication range of the system, which depends on several factors, such as relief topography and High buildings, type of the antenna used, antenna position and how to find good sensors for voltage and current with low price and high efficiency.

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